Arthur Holmes. In the main, Holmes's inferences are confirmed. It is found that the available compression is probably sufficient to account for all existing mountains, and an explanation of the Pacific type of mountain range is based on the greater cooling and consequent strength of the sub-oceanic rocks. A physical interpretation of the results of investigations of isostasy is offered, and is used in a discussion of the compensation of oceanic inequalities. It is shown that the inequality that gives rise to the land and water hemispheres is necessarily compensated, and that the oceans are also in the main probably compensated. An explanation of the fact that the great oceans have regions of smaller depth in the middle is founded on the greater cooling of sub-oceanic rocks. This theory requires that the deeper parts of the oceans should be associated with low values of gravity, which is capable of direct verification.

The stresses that would be set up in the earth's crust soon after solidification are discussed, and the results appear to agree with observations of the present state of the moon. A theory of the origin of continents is developed from this, and appears to have certain important advantages over those at present current.

On the Absorption of Light by Electrically Luminescent Mercury Vapour.

By E. P. METCALFE and B. VENKATESACHAR.

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[PLATE 3.]

Introductory.

Some of the earliest experiments on the absorption of light by electrically luminous gases were carried out by Pflüger,* who, in 1907, investigated the absorption and reversal of the hydrogen lines by luminous hydrogen. He used a condensed discharge in a three-electrode tube, in which a short constriction provided the source of radiation and the wider and longer part the absorbing column. He succeeded in reversing H_α. This work was followed up by Landenburg and Loria,† who reversed H_α and H_β. In the same year

* 'Ann. der Phys.,' vol. 24, p. 515 (1907).
† See Wood's 'Physical Optics,' p. 434.

Kuch and Retschinsky* made experiments on selective absorption in mercury vapour lamps. They found that the ratio of the intensities of the spectral lines in the light from the mercury vapour depends on the thickness of the radiating layer of vapour, the intensities of neighbouring lines tending to equalise as the layer increases in thickness, a result which would follow from a relatively greater absorption of the stronger lines. They also made photometric measurements of the illumination from two mercury lamps, one of which was placed behind the other so that the light from the first had to traverse the second. They discovered that the radiation from the combination of lamps, arranged thus, was less than the sum of the radiations from each separately. Pflüger† followed with photometric observations on the absorption of the lines 5461 Å.U., 4358 Å.U., 4047 Å.U., 5791 Å.U., and 5770 Å.U. Similar work was done by L. Grebe,‡ on 5461 Å.U. and 4358 Å.U. In all these experiments with luminous mercury vapour, the current densities (of the order of 2 ampères per square centimetre) and the power developed in the absorbing arcs were considerable.

Preliminary Experiments.

It occurred to the present writers that very faintly luminous mercury vapour might possibly exhibit more marked selective absorption than had been observed by previous experimenters. It was, therefore, thought worth while to look for a means of maintaining a mercury arc of very low current density. This was found possible in a three-electrode tube in which two arcs were formed, having a common cathode. This arrangement, which is somewhat similar to that used in "self-starting" vapour lamps, is shown in fig. 1. A strong arc is started between mercury pools K and A in the lower part of the vacuous tube; the third electrode B being a thick iron wire cemented in with sealing wax. Connections are made as shown. The apparatus having been pumped out to a very low pressure, an arc is struck between A and K, B being connected to the supply through a rheostat. When the ionised vapour from the arc AK reaches B, the second arc BK starts, taking a current whose strength depends on the resistance R_2. This current strength can be indefinitely diminished by increasing R_2. The low power arc BK can only be maintained in the presence of the strong ionising arc AK. If the pressure in the tube is sufficiently low and the current in BK is of the order of 0·1 ampère, the second arc fills the tube with a characteristic faint luminosity. In this state the vapour is found to exhibit marked selective absorption.

* 'Ann. der Phys.,' vol. 22, p. 852 (1907).
† 'Ann. der Phys.,' vol. 26, p. 789 (1908).
‡ 'Ann. der Phys.,' vol. 36, p. 834 (1911).

Our first experiments were made with a bulb of this sort, through which was passed the light from an independent mercury vapour lamp carrying a

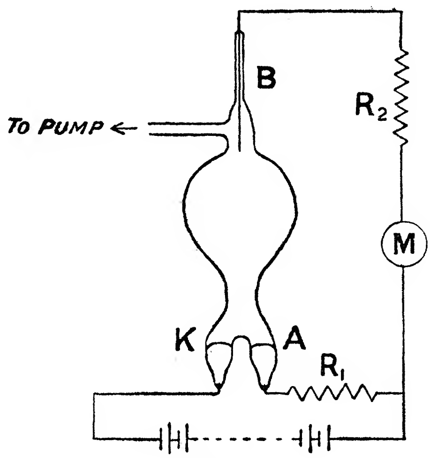


FIG. 1.

current of density about 5 ampères per square centimetres. The radiating arc was placed close to the bulb and the light traversing the bulb was focussed through a green ray filter on to a glass Fabry and Perot étalon of 5 mm. thickness. The ring system was examined while the arc BK was turned on and off. After several trials an indication of a diminution in the brightness of the rings was observed as the arc BK started. We then removed the green ray filter and placed a small piece of white paper at the focus. As the arc BK started, a very perceptible change was observed to take place in the tint of the image of the mercury lamp, the colour becoming distinctly pinkish. The effect was well marked when the current density of BK was of the order of 5 milliampères per square centimetre. It was soon found that, to produce the effect at all, it was necessary that the tube should be very completely pumped out—the more completely the better. Using the Fabry and Perot étalon, it was found possible with this tube, when the conditions were most favourable, to observe a faint dark line in the middle of each ring in the main line system.

It seemed very highly probable that the smallness of the absorption effect in these experiments was due to the shortness of the absorbing column provided by that particular shape of tube. So that our next step was to contrive a form of apparatus giving us a much longer—and also a variable length of—absorbing column.

Description of Apparatus and Mode of Working.

Our apparatus finally took the form shown diagrammatically in fig. 2. L_1, L_2 is a glass tube of 3 cm. bore and 110 cm. in length. A_1, A_2, A_3 are

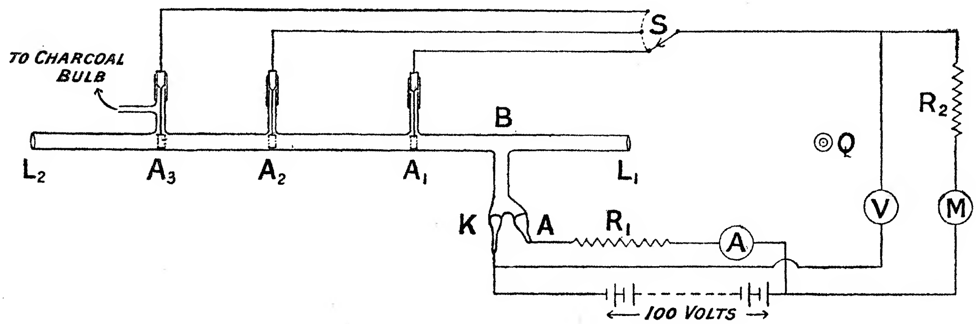


FIG. 2.

three iron ring-electrodes, forming anodes for the absorbing arc. A and K represent the mercury anode and cathode of the ionising arc. K forms a common cathode for the ionising arc KA and the absorbing arc between K and any one of the three ring electrodes. Thus we were able to experiment with absorbing columns of 13 cm., 35 cm., and 52 cm. respectively. The ends of the tube were closed by quartz lenses L_1 and L_2 of focal lengths 30 cm. and 75 cm. respectively. The light from a radiating mercury vapour arc, produced in a narrow vertical silica tube, placed at Q, was rendered parallel by the lens L_1 and, passing through the ring electrodes, was focussed by L_2 on the slit of the spectroscope or on the Fabry and Perot étalon with which observations were made. For work with the longest column it was found necessary to keep the length of the tube between B and A warm. This was done by winding an iron wire heating coil round the tube and lagging it with asbestos fabric; this coil was included in the ionising arc circuit. Underneath the heating coil, and insulated from it, we inserted four iron-german-silver thermo-couples (at B, A_1, A_2 and A_3) in contact with the glass of the tube. These thermo-couples indicated temperatures on a millivoltmeter. For the sake of clearness the heating coil and the thermo-couples are not shown in the diagram. About 20 cm. of each end of the tube remained cool, so that mercury did not condense on the lenses. The main tube was of ordinary soda glass, the part containing the ionising arc being of lead glass welded to a soda glass tube below B.

With this apparatus, under suitable conditions, it was found possible to absorb 80 per cent. of the incident green radiation from the vapour lamp at Q, the radiation from the absorbing column itself being practically negligible.

Subsequent observations made with an échelon spectroscope showed that the unabsorbed light (*i.e.*, about 20 per cent. of the incident light) is due to the satellites of the main line in the 5461 Å.U. group, the main line itself being almost entirely absorbed. The magnitude of the absorption is very striking, considering the extreme tenuity of the vapour in the column, the lowness of the current density and the feeble luminosity of the absorbing column. We may take, as an example, an observed case where the highest temperature of the glass containing the absorbing column was about 100° C., the lowest temperature being 50° C., with a current density in the absorbing arc of about 10 milliampères per square centimetre a column of luminescent vapour 52 cm. in length absorbed 80 per cent. of the incident green radiation from the bright vapour lamp at Q.

A typical experiment with this apparatus is conducted thus. Electrical connections having been made as shown in the diagram, the tube is evacuated as thoroughly as possible with liquid-air-cooled charcoal. The arc AK is struck. The vapour from this arc rises into the horizontal part of the tube. The three-point switch, S, is connected to A_1, and a voltmeter connected between A_1 and K shows 100 volts. An observer, looking through either of the lenses L_1 and L_2, can see an advancing ring of condensing mercury on the sides of the tube, moving towards A_1. As this ring, which marks the head of the column of ionised vapour, reaches A_1, the voltage A_1K gradually falls to about 60, and a discharge is seen to start, of a bright bluish-white colour. This is followed by a sudden drop in the voltage to about 20, accompanied by an equally sudden change in the colour of the discharge, as seen end-on, which becomes distinctly pinkish. It is found that the absorption produced by the bluish discharge is slight, whereas that produced by the pinkish discharge may be enormous.

A similar series of events is associated with the approach of the ionised vapour to the anodes A_2 and A_3.

Measurements of Absorption.

With this apparatus we proceeded to measure the absorption, using a Lummer-Brodhun photometer. The light passing through the lens L_2 was made, by means of an additional lens, to form a uniform patch of illumination on one face of the white screen of the photometer; the other face of the screen was illuminated by a comparison mercury vapour lamp, mounted so as to slide along a 2-metre photometer bench. The position of the comparison lamp was controlled by the observer by means of a simple winch arrangement close to the photometer eyepiece. Observations were made through a green ray filter. The thermal and electrical conditions in the radiating and

comparison lamps were kept constant, as also those in the ionising arc, AK; the current in the absorbing column was variable from zero to 0·2 ampère. Sets of typical observations are given in Tables I and II.

Table I.—Length of Absorbing Column 13 cm. Voltage Drop between A_1 and K 23·5 volts.

Current density in absorbing column. Milliamps. per sq. cm.	Fraction of incident light transmitted.
3·72	0·52
5·32	0·46
6·92	0·40
7·98	0·37
9·32	0·35
10·64	0·34
11·95	0·33
13·30	0·33

Table II.—Length of Absorbing Column 35 cm. Voltage Drop between A_2 and K 53 volts.

Current density in absorbing column. Milliamps. per sq. cm.	Fraction of incident light transmitted.
0·75	0·89
1·00	0·70
2·71	0·34
5·42	0·29
8·12	0·29
13·55	0·22

With the 52-cm. column the absorption is so heavy that a succession of measurements of progressive absorption is hardly possible, since the limiting value of the transmitted fraction is reached with a current density of 1 milliampère per square centimetre. The voltage drop between A_3 and K in this case was 75 volts. The observations recorded in the two Tables above are plotted in fig. 3.

It must be noted that in the above experiments the radiation from the absorbing column is negligible, and the fraction of the incident light transmitted tends to a limiting value which appears to represent the ratio of the sum of the intensities of the satellites of the main line to that of the complete group constituting 5461 Å.U. The satellites are only very slightly (indeed quite imperceptibly) absorbed under the conditions of the experiment recorded in Table I (viz., low current density and shortness of absorbing

column). As will be mentioned later, one of the satellites has been observed to be absorbed under certain very favourable conditions.

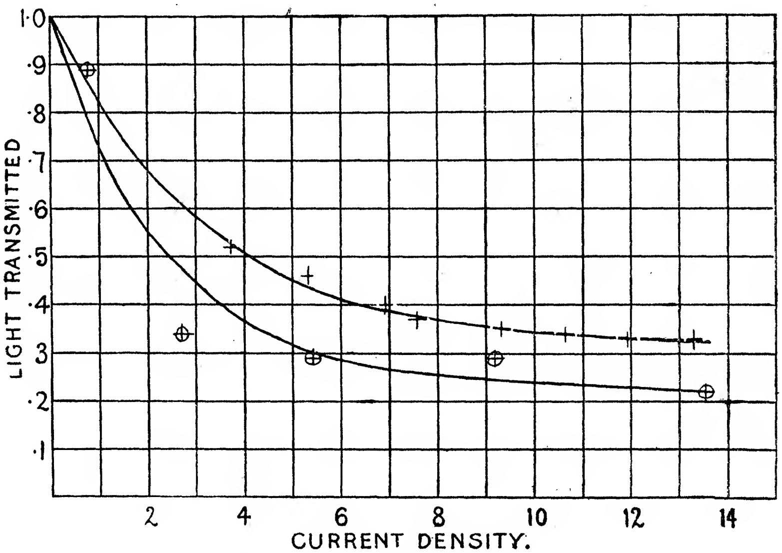


FIG. 3.

Measurements of Radiation.

Previous workers have investigated the relationship of the amount of light radiated from the mercury vapour arc to the absorbing power of the luminous vapour when the power consumed in the absorbing arc is varied. They have thus connected values of the ratio (emission/absorption) with values of the power consumed. It has been thought that the results of these experiments suggests that part of the radiation is to be regarded as a temperature effect. We were led by these considerations to attempt to measure the intensity of the light radiated along the axis of our absorbing column and to connect it with the current density in the absorbing column. This was done with the same photometer arrangement as already described, the radiating arc at Q being of course extinguished. By suitable optical arrangements, the light passing through the lens L_2 was made to produce a uniform illumination over the photometer screen. On account of the feebleness of the illumination it was found necessary to cut down the illumination from the comparison lamp by means of a narrow horizontal slit, which permitted only the light from a short length of the vertical vapour lamp to pass through. Typical measurements of the axial radiation of wave-length 5461 Å.U. are given in Tables III, IV, and V. The unit of illumination is arbitrary and is only approximately the same for the three Tables.

Table III.—Length of Column 13 cm.

Current density. Milliamps. per sq. cm.	Relative illumination.
5·5	1·0
8·2	1·8
11·0	2·8
13·7	4·0

Table IV.—Length of Column 35 cm.

Current density. Milliamps. per sq. cm.	Relative illumination.
8·1	2·0
9·1	2·4
10·8	3·0
11·9	3·6
13·5	4·0
14·8	4·6
16·4	5·2
21·4	7·4

Table V.—Length of Column 52 cm.

Current density. Milliamps. per sq. cm.	Relative illumination.
3·4	0·8
4·0	0·9
5·4	1·3
7·0	1·7
8·1	2·2
10·0	2·8
13·5	4·0
16·3	5·0

The results given in Tables III, IV, and V are shown graphically in fig. 4. The shapes of the curves distinctly suggest a linear relationship between current density and emission, except in the case of the 13-cm. column, where the curve is slightly concave upwards.

The intensity of the radiation emitted along the axis from the end of a uniform tube containing a luminous and absorbing medium is given by the expression $(\mathrm{I}/a)(1-e^{-al})$, where $\mathrm{I}dx$ represents the intensity of the radiation from a layer of thickness dx, a the coefficient of absorption, and l the length of the tube. When al is large, the radiation is simply I/a. Thus the

curves obtained show that the relation between the ratio I/a and the current density is linear, the slight initial concavity being due to the influence of the second term in the expression.

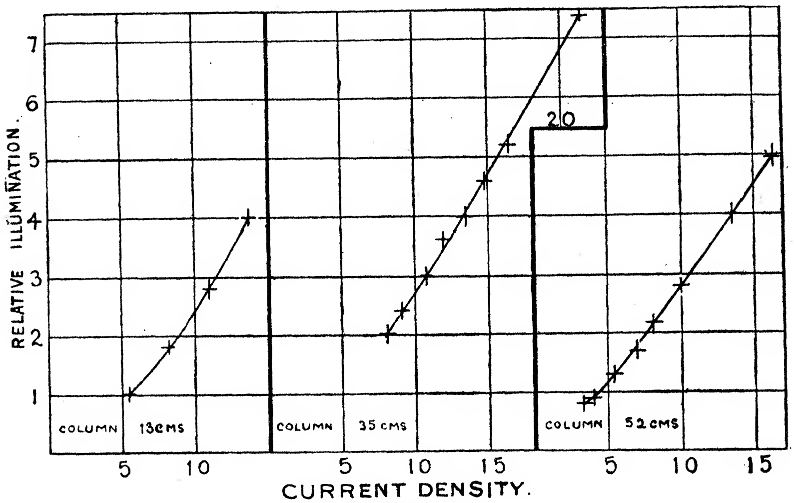


Fig. 4.

This result resembles to some extent that arrived at by L. Grebe from experiments on the absorption of the light from one mercury vapour lamp carrying a large current by a second vapour lamp, also carrying a large current. The important difference exists between Grebe's method of attacking the subject and that employed by us, that in our experiments the current densities used are so low, and the additional power developed in the column to render it luminous is so small compared with that required to keep up the temperature of the tube (*i.e.*, that developed in the heating coil and the ionising arc), that the temperature may be regarded as constant, and not depending on the illuminating current; whereas, in Grebe's work, an increase of temperature proportional to the power developed in the lamp was assumed. The power developed by our absorption current was never greater than 9 watts, while in Grebe's experiments the power in the absorption current ranged between 116 and 517 watts. In our experiment the temperature indications of the thermo-couples remained unaltered throughout a series of observations. We are forced to conclude that, under the conditions of our experiments, the increase of radiation is not to be ascribed to increase of temperature.

Absorption of other Lines.

Our photometric observations were confined to the green line (5461 Å.U.). We did, however, make an attempt to gain an idea of the extent to which light of other wave-lengths is absorbed by the luminous vapour. Photographs were taken with a concave grating spectrograph of 10 feet radius of the spectrum of the light from a silica mercury vapour lamp which passed through the experimental tube. Two spectra were photographed on the same film, the girder being slightly displaced between the two exposures. One exposure was made with the vapour column non-luminous; the second, of equal length, with the vapour luminous. Inspection of the developed film showed that the different mercury arc lines suffered very variable amounts of absorption. The results of this experiment are tabulated in Table VI.

Table VI.

I. Lines Perceptibly Absorbed.

Å.U.		
5461	strongly	First triplet ($m = 2 \cdot 5$) of the second subordinate series of triplets.
4359	"	
4047	"	
3342	very strongly	First member of second triplet of above series.
3663	strongly	First triplet ($m = 3$) of the first subordinate series of triplets.
3132	very strongly	
2967	"	

Å.U.		Å.U.	
5289	slightly.	3650	strongly.
5295	"	3342	very strongly.
5308	"	3126	"
3655	strongly.		

II. Lines not Perceptibly Absorbed.

Å.U.	
5791	Lines ($m = 3, 4, 5$) of Paschen's first subordinate series of single lines.
4347	
3907	
4916	Third line ($m = 3 \cdot 5$) of second subordinate series of single lines.
5770	Lines of Paschen's combination series.
4339	
4078	
5068	
3984	

These results are, of course, to be regarded only as rough indications of the extent to which the various lines are absorbed. It is very probable that photometric measurements would show some degree of absorption in most of the lines given in the second list. In the case of 2536 Å.U., which is absorbed by non-luminous mercury vapour, the absorption is not apparently increased when the vapour is rendered luminous. Though the yellow lines (5791 Å.U. and 5770 Å.U.) are two of the brightest lines in the mercury arc spectrum, they are not strongly absorbed. With regard to these two lines, our experience is much at variance with that of Pflüger,* who records a heavy absorption for both of them. The divergence between our respective results may be due to the great difference of the conditions, Pflüger's work having been conducted with absorbing arcs of large current density.

Kuch and Retschinsky deduced the existence of absorption in the case of some of the ultra-violet lines from a comparison of photographs of the spectra of the radiation from the ends of short and long columns of luminous mercury vapour. In Table VI above we have now direct evidence of absorption of ultra-violet lines.

Application of the Stewart-Kirchhoff Law to Bright Line Radiation.

Previous workers have given much attention to the question of the applicability of the Stewart-Kirchhoff law, or a modification of that law, to the line radiation from luminous gases. This law holds rigorously in the case of pure temperature radiation (such, for example, as the radiation from CO_2 at $\lambda = 4{\cdot}3\,\mu$).

If the radiation from a source between the wave-lengths λ and $\lambda+d\lambda$ be $\mathrm{E}\,d\lambda$, and its absorption for the same range of wave-length be a, then

$$\frac{\mathrm{E}\,d\lambda}{a} = \mathrm{I}\,d\lambda, \tag{1}$$

where $\mathrm{I}\,d\lambda$ represents the radiation of a black body for that range at the temperature of the actual radiating body. This states the law for pure temperature radiation. For other than pure temperature radiation, $\mathrm{I}\,d\lambda$ represents the radiation, for that range, of a black body at the "emission temperature," the emission temperature being the temperature at which the emission of a black body is equal to the ratio of the emission to the absorption of the radiating body.

Imagine two ordinary mercury vapour lamps, emitting the same spectral lines, so placed that the radiation from one, P, passes through the other, Q.

* 'Ann. der Phys.,' vol. 26, p. 805 (1908).

Let us consider a single line, of which the widening is due entirely to the temperature Doppler effect. This supposition is warranted, in the case of gases at low pressure, by the experimental results of Michelson and of Buisson and Fabry.

For the energy distribution in a spectral line emitted by a gas we have

$$\mathrm{E}\, d\lambda \propto d\mathrm{N} \propto e^{-u^2/2\mathrm{R}\theta}\, du = e^{-\beta u^2}\, du, \tag{2}$$

where $d\mathrm{N}$ is the number of molecules whose velocities resolved in the line of sight lie between $u+du$, R is the gas constant, and θ the absolute temperature.

If λ_0 is the wave-length corresponding to the middle of the line, and λ the wave-length corresponding to a velocity u in the line of sight, then

$$\lambda = \lambda_0\left(1+\frac{u}{c}\right), \tag{3}$$

where c is the velocity of light and

$$du = \frac{c}{\lambda_0}\, d\lambda.$$

Substituting in (2), we have

$$\mathrm{E}\, d\lambda \propto \frac{c}{\lambda_0}\, e^{-k(\lambda-\lambda_0)^2}\, d\lambda,$$

where

$$k = \beta\frac{c^2}{\lambda_0^2},$$

or

$$\mathrm{E}\, d\lambda = \mathrm{E}_0\, e^{-k(\lambda-\lambda_0)^2}\, d\lambda, \tag{4}$$

where E_0 is the intensity in the middle of the line. For the radiation between λ and $\lambda+d\lambda$ from the lamp Q we have

$$\mathrm{E}\, d\lambda = \mathrm{E}_q\, e^{-k_q(\lambda-\lambda_0)^2}\, d\lambda, \tag{5}$$

and for that from the lamp P,

$$\mathrm{E}'\, d\lambda = \mathrm{E}_p\, e^{-k_p(\lambda-\lambda_0)^2}\, d\lambda. \tag{6}$$

The radiation within this range of wave-length which is emitted by P and absorbed by Q is

$$a\, \mathrm{E}_p\, e^{-k_p(\lambda-\lambda_0)^2}\, d\lambda,$$

where a is the absorption, *i.e.*, the fraction of the incident light which Q absorbs.

From (1) and (5)

$$a = \frac{\mathrm{E}_q}{\mathrm{I}}\, e^{-k_q(\lambda-\lambda_0)^2},$$

so the radiation absorbed is given by

$$ds = \frac{\mathrm{E}_p\mathrm{E}_q}{\mathrm{I}}\, e^{-(k_p+k_q)(\lambda-\lambda_0)^2}\, d\lambda.$$

Integrating over the whole width of the line. we have for the radiation absorbed by Q

$$s = \frac{E_p E_q}{I} \int_{(\lambda-\lambda_0)=-\infty}^{(\lambda-\lambda_0)=\infty} e^{-(k_p+k_q)(\lambda-\lambda_0)^2} d\lambda = \frac{E_p E_q}{I} \sqrt{\left(\frac{\pi}{k_p+k_q}\right)}. \tag{6A}$$

The light radiated by P is given by

$$S_p = E_p \int_{(\lambda-\lambda_0)=-\infty}^{(\lambda-\lambda_0)=\infty} e^{-k_p(\lambda-\lambda_0)^2} d\lambda = E_p \sqrt{\left(\frac{\pi}{k_p}\right)}. \tag{7}$$

Therefore,

$$\frac{s}{S_p} = \frac{E_q}{I} \sqrt{\left(\frac{k_p}{k_p+k_q}\right)} = A. \tag{8}$$

This ratio A is what is actually measured in experiments on the absorption of a single line radiation.

The emission from the lamp Q is given by

$$S_q = E_q \sqrt{\left(\frac{\pi}{k_q}\right)}. \tag{9}$$

Therefore the ratio (emission/absorption) of Q, as measured, is

$$\frac{S_q}{A} = I \sqrt{\left(\pi\left[\frac{1}{k_p}+\frac{1}{k_q}\right]\right)}. \tag{10}$$

Substituting for k the value

$$\beta \frac{c^2}{\lambda_0^2} = \frac{1}{2R\theta} \cdot \frac{c^2}{\lambda_0^2},$$

$$\frac{S_q}{A} = \frac{\lambda_0}{c} I \sqrt{(2\pi R[\theta_p+\theta_q])}, \tag{11}$$

or,

$$A = \frac{c}{\lambda_0} \frac{S_q}{I} \sqrt{\left(\frac{1}{2\pi R[\theta_p+\theta_q]}\right)}, \tag{12}$$

where θ_p and θ_q are the absolute temperatures of the vapour in P and in Q respectively.

From this it appears that in the case of pure temperature radiation, or of radiation following the modified form of the Stewart-Kirchhoff law, referred to above, the conditions in the absorbing vapour being maintained constant, an increase of temperature in the radiating arc will diminish the coefficient of absorption as measured. It is easy to see that this must be so, since the increase of temperature will widen the radiated line, the absorption line remaining of constant width. In fact, any cause which will widen the radiated line will decrease the coefficient of absorption, because a greater proportion of energy will be radiated in the outer parts of the widened line, where the absorption is less than in the middle. To test this conclusion, we made some experiments in which the widening of the radiated line was

produced by increasing the current in the radiating arc. The results are given in Table VII.

Table VII.

Current density in absorbing column. Milliamps. per sq. cm.	Current in radiator amps.	Absorption A.
14	1·5	0·71
	3·0	0·58
7	2·0	0·56
	3·0	0·48

These results show definitely that, when the absorption is as sharply selective as that we are now discussing, the absorption coefficient for a single line radiation (as usually measured) depends on the conditions in the radiator as well as those in the absorber.

The complexity of a spectral line must have a great influence on the apparent absorption of the line, if the modified Stewart-Kirchhoff law holds. For example, let W_1 and W_2 be two neighbouring lines radiated by the lamp P and absorbed by the lamp Q. Of these lines, suppose that W_1 is made up of two close components of equal intensity, actually separate and not overlapping, but too close for resolution by the apparatus employed to observe them. Let the complex line W_1 and the single line W_2 appear equally bright. Then the absorption of each member of the doublet W_1 may be taken as A (see equation 11, above) and the emission of each as S_p. The light absorbed by Q from each member will be AS_p, so that the total light absorbed from W_1 will be $2AS_p$. The emission of the single line W_2 will be $2S_p$, and if the modified form of the Stewart-Kirchhoff law holds, the absorption of the line W_2 will be 2A. So that the light absorbed from the single line will be $2A2S_p$. Thus the absorption of the line W_2 will appear to be double that of W_1, the ratio emission/absorption of each component of W_1 being the same as that of W_2 (see equation (11) above)). It is evident that the modified form of the law will fail if W_1 and W_2 are treated as two single lines, whereas it will hold if the two components of the doublet W_1 and the single line W_2 are treated (as they should be treated) as three separate lines.

A possible example of the application of these considerations may be supplied by the case of the two bright yellow mercury lines. Of these, Pflüger states that 5790 Å.U., the brighter, is less absorbed than 5770 Å.U., the less bright. But even though (E/a) were constant throughout the structure of both lines, this might be the case if the brighter line were more complex than the other. It is interesting to observe that Prof. R. W. Wood's

photographs of the two lines* show that the line 5790 Å.U. is very much more complex than 5770 Å.U.

On the Reversal of the Mercury Lines.

Many of the mercury lines have been observed to be self-reversed in the spectrum of the unenclosed mercury arc at atmospheric pressure. Perot† records an observation of the self-reversal of the main component of the green line from a mercury vapour lamp viewed end-on, with an air étalon of 1 cm. thickness.

Our own study of the reversal may be divided into two parts: the first part consisted of experiments with a silica mercury vapour lamp as the source of radiation; the second of an attempt to produce a reversed dark line on the continuous background of the white light spectrum of a carbon arc, and, later, on the solar spectrum. In all these experiments, the absorption took place in the low current arc already described.

In the first series of experiments, the light from the silica lamp was made to pass, as before, through the experimental tube in a parallel beam, being then brought to a sharp focus by the lens L_2 on to a small hole drilled in an opaque screen. Close behind the screen was placed a glass plate étalon of 5 mm. thickness. In this way the effect of the diffuse illumination from the absorbing column was minimised. The ring system was observed, as usual, through a small telescope. A green-ray filter was placed between L_2 and the perforated screen. If the pressure in the radiator arc is small, the appearance of the rings is as shown in (Plate 3, fig. 5*a*), which is from a photograph taken with the actual apparatus. In this photograph, besides the main line system, two satellite systems are seen. One of these is $\lambda + 0{\cdot}09$ Å.U., the rings of which lie just within the corresponding main line rings. The other is $\lambda - 0{\cdot}07$ Å.U.; its rings lie just outside the corresponding main line rings.

For the purpose of the reversal experiments, we used a rather higher pressure in the radiator, thus widening the lines slightly. The appearance of the rings under the higher pressure is shown in the right-hand half of fig. 5*b*. On gradually increasing the current in the absorbing column from a very low value, the following series of changes in the appearance of the ring system takes place. At first, with the lowest current, the main line rings become darker. As the absorbing current increases, a fine dark line appears in each main line ring. At this stage, the split main line and the satellite $\lambda - 0{\cdot}07$ Å.U. appear like three close lines, somewhat resembling a Zeeman triplet. After this the absorption dark line broadens,

* 'Phil. Mag.,' vol. 25, p. 443 (1913).

† 'Comptes Rendus,' vol. 148, p. 404 (1909).

and the general diminution of brightness of the main line system, together with the absence of appreciable absorption of $\lambda - 0\cdot07$ Å.U., renders the line of demarcation between the main line and $\lambda - 0\cdot07$ Å.U. less distinct. This gives an appearance of asymmetrical reversal of the main line.

This stage is represented in the left-hand half of fig. 5*b*. Looking at the photograph, we see in the left-hand half a series of pairs of strong dark lines. The outer line of each of these pairs is the reversed absorption line. It will be seen that each of these absorption lines corresponds to a bright line in the right-hand half of the figure. Each absorption line is bounded by two bright lines, of which the inner bright line is the unabsorbed edge of the widened main radiation line; the outer bright line is made up of the other edge of the main radiation line and the satellite $\lambda - 0\cdot07$ Å.U., which coalesce. Outside, and very close to this latter line, is the satellite $\lambda + 0\cdot09$ Å.U. If the pressure in the radiating arc is kept very low by means of a liquid air-cooled charcoal bulb, the main radiation line is so narrow that the unabsorbed edges are not visible; and gradually increasing the absorbing current merely has the effect at first of progressively diminishing the brightness of the main line system until the satellite systems alone remain visible.

The green line 5461 Å.U. is a group consisting of at least seven lines. The reader is referred to the beautiful photograph of the group by Prof. McLennan.* We have photographed the line with a small échelon of twelve 1 cm. plates, using the light radiated along the axis of our absorbing column, the spectroscope slit being placed sufficiently far from the end of the column to ensure that all parts of the column should be nearly equally effective. With a column length of 52 cm. and a current density of 0·3 ampère per square centimetre, all the light being thrown into one order of the échelon, the brightness of the satellites was seen to be very greatly enhanced, so that they became hardly distinguishable in brightness from the main line itself. The equalisation of the brightness of the satellites under these conditions points to the existence of absorption in the case of the brighter members of the group, and suggests the possibility of the reversal of some of the brighter satellites. This consideration led us to search for reversals of satellites and we succeeded in observing the reversal of $\lambda + 0\cdot09$ Å.U. For this we employed the same arrangement of the étalon as was used for observations on the main line reversal, with which the photographs fig. 5*b* were taken. A widened line was produced by admitting air into the radiator arc. A large image of the ring system was formed by a long focus lens and a pointer was adjusted to the position of one of the satellite rings. The region round the pointer was

* 'Proc. Roy. Soc.,' A, vol. 87, Plate 4, fig. 1.

examined with an eye-piece. On switching on the 52-cm. absorbing column current, a dark ring appeared on the pointer. The pointer is necessary on account of the complexity of the reversal pattern, the main line itself being, of course, reversed. This observation of the reversal of a satellite supports the conjecture that multiple reversals such as are observed in the lines of metal arc spectra may be due to reversals of satellite lines.

The reversal experiments just described were all carried out with a bright vapour lamp as radiator. The results of these experiments suggested an attempt to produce an absorption spectrum of the luminescent vapour on the white light spectrum of an ordinary carbon arc. For this we used a concave grating of 10 feet radius and 45,000 lines. The line was seen reversed in the first order. We succeeded in reversing the line 5461 Å.U. and 4359 Å.U. on the carbon arc spectrum. We reproduce a photograph of the reversed green line on the background of the solar spectrum. The photograph was taken in the second order. In fig. 6, Plate 3, two photographs of the solar spectrum in this region are placed in juxtaposition, one showing the reversed mercury line. A wave-length scale graduated in single Å.U.s is attached. These two photographs were taken under the same conditions, except that in the case of one of them the column of mercury vapour traversed by the solar light was made luminous by the passage of a small current.

The reversal of the green line on a continuous spectrum forms a very striking experiment. To see it, an absorbing arc of 10 cm. length or more should be used, and the absorption tube should have been well exhausted with the liquid air-cooled charcoal. The white-light background spectrum being bright, the reversed line appears on closing the absorbing arc circuit. The reversal can be seen with a current density of only 1/10 milliampère per square centimetre in the 52-cm. column. A slightly higher current, however, produces a better defined line. It is possible to reverse the line on the continuous spectrum of a tungsten filament lamp.

Reference has already been made to the pinkish tint of the light emitted by the absorbing column when observed along the axis of the tube. This, of course, is due to the heavy absorption of the bright green and blue lines and to the enhancement of the red and yellow radiations due to the length of the radiating column combined with low absorption. The pink tint is characteristic of low current density discharge. As the current density increases, the light radiated along the axis of the tube regains the usual colour of the mercury arc.

Our observations on the reversal of the green line show that the absorption is greatest in the middle of the line and falls off on either side. The effect of this is to increase the brightness of the edges of the radiation line

relatively to the middle when the light is radiated along the axis of a long column. In other words, the radiation line seen along the axis of a column is wider than that emitted from the side of a narrow tube. This is the fifth cause of widening enumerated by Lord Rayleigh.* He observes that "It must certainly operate, but does not appear to be important in practice." Examination of the group 5461 Å.U., with the twelve-plate échelon along the axis of our 52-cm. column, with a current density of 0·2 ampère per square centimetre, showed the lines less sharp than those from an ordinary low pressure lamp. Whether this effect is really due to the cause of widening alluded to above, or whether it is to be attributed to the increased brightness of the satellites is not certain, the resolving power of the échelon being hardly sufficiently high to warrant a definite conclusion. It is possible that an instrument of higher resolving power would definitely reveal the existence of this kind of widening in the lines radiated from the ends of long columns of vapour of low density, such as we have employed.

Summary.

1. Experiments are described in which mercury vapour at low pressures, rendered luminous by the passage of small electric currents, is found to exert powerful selective absorption.

2. A list of wave-lengths found to be absorbed is given. It is found that, of the series lines, those belonging to the first and second subordinate series of triplets exhibit heavy absorption.

3. Photometric observations are recorded on the absorption and emission of 5461 Å.U. by columns of mercury vapour of different lengths and carrying different currents.

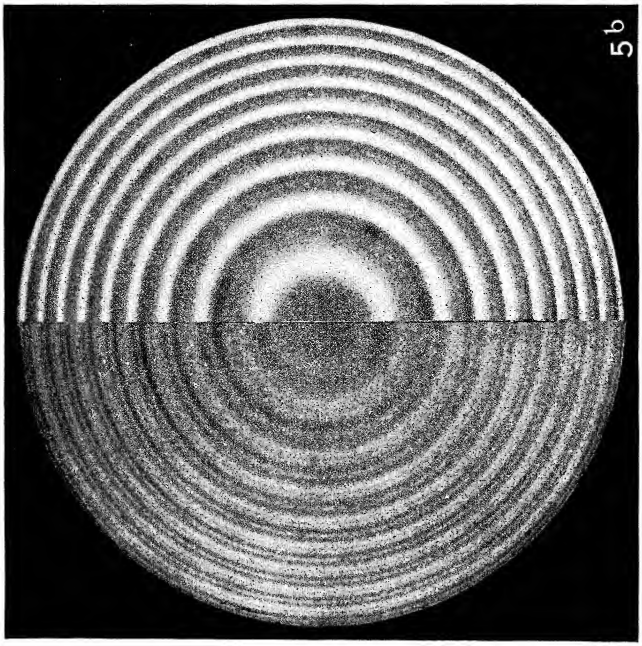
4. The relation between the ratio (emission/absorption) and the current density is found to be linear.

5. The applicability of the Stewart-Kirchhoff law to bright-line radiation is discussed; and it is shown that the complexity of a line may have a great influence on its absorption.

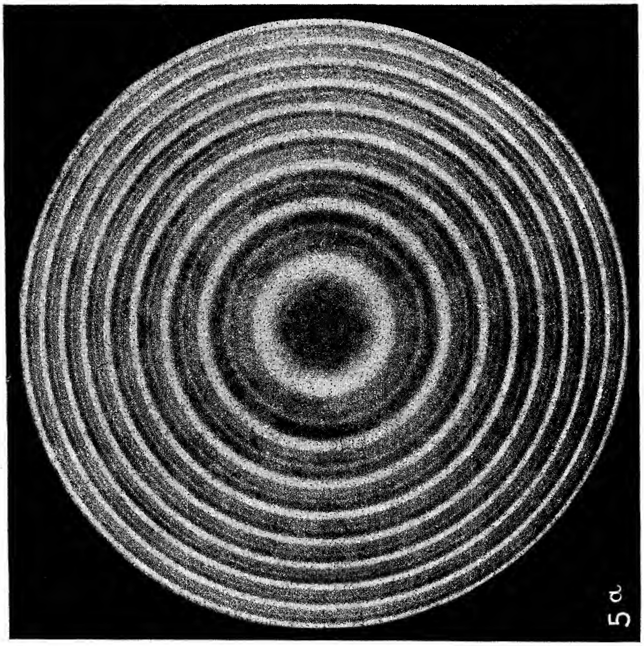
6. The lines 5461 Å.U. and 4359 Å.U. have been reversed, so as to appear as dark lines on the white-light spectrum of a carbon arc and of the sun.

7. The reversal of 5461 Å.U. has been studied in detail with a Fabry and Perot étalon and with an échelon spectroscope.

* 'Phil. Mag.,' vol. 29, p. 274 (1915).



5 b



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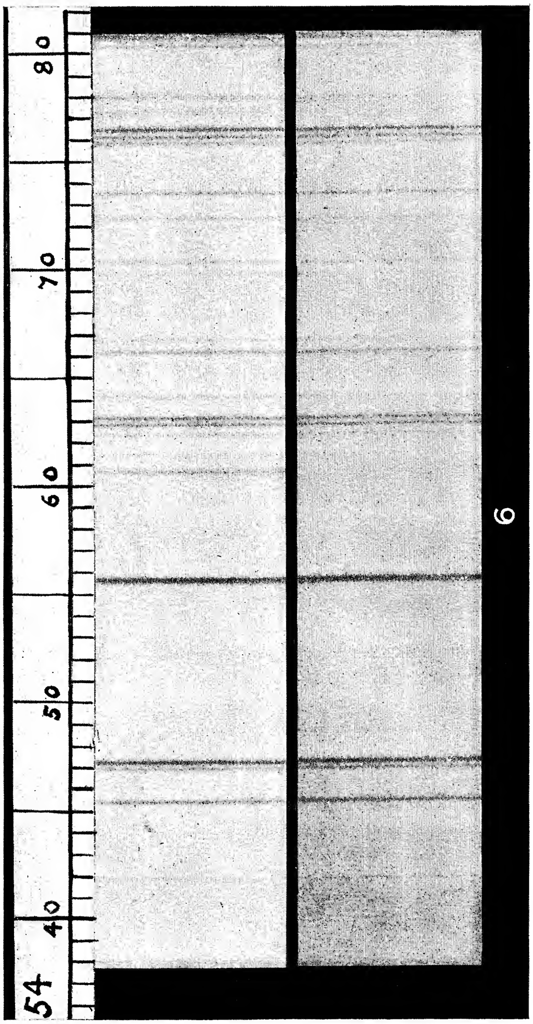

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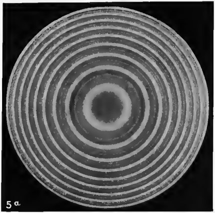

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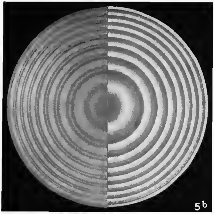

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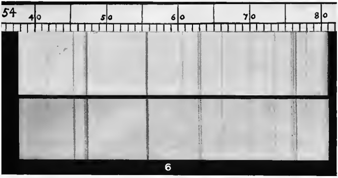

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